The Regional Woodshed

Middlebury College
Environmental Studies 401
Transboundary Issues in Sustainability

Spring 2013

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I. Executive Summary

The goal of this project was to better understand the Vermont Regional Woodshed by mapping the movement of biomass fuels in and out of the state and considering current policy and science surrounding carbon accounting. We approached this project from three angles: looking at the most current scientific research concerning the carbon emissions of biomass harvesting and utilization, researching the policy that surrounds the biomass industry, and talking to suppliers and end-users about the spatial patterns of biomass harvesting and transportation.

For the purposes of this study we have defined the Vermont Regional Woodshed as the region from which biomass consumed within the state of Vermont is harvested, as well as the region to which biomass harvested in Vermont is distributed. This primarily includes Quebec, New Hampshire, New York, Massachusetts, Connecticut, Maine and Rhode Island.

We found that biomass harvesting poses specific challenges to environmental quality. Because it incentivizes whole-tree harvesting, the practice may deplete soil fertility and remove structure important to wildlife. Though biomass harvesting and utilization is often classified as carbon neutral, net emissions are largely dependent on harvesting practices and long-term forest management.

In our policy review, we will show how state and federal regulations focus on the harvesters and often neglect the rest of the supply chain, leaving suppliers to assume that loggers are complying with standards. Also, power plant procurement standards provide the only real control over the management and harvesting practices currently in place.

We discovered that the vast majority of policies focused on harvesting practices at the site-specific level, and were not explicitly regulated by state or federal agencies. Other US states with similar forest resources have voluntary BMPs, which act as guidelines for biomass harvesting. Vermont, however, is currently lacking BMPs, which we have highlighted as an area for improvement. One other policy gap we identified is the lack of a regionally consistent definition for “sustainably harvested” biomass, which we believe is important for preserving forest health and long-term sustainability. A possibility for improvement lies in RGGI, which has already established a platform for regional cooperation on issues of resource management and sustainability.

After contacting approximately 50 biomass suppliers and end-users in and around the state of Vermont, we were able to map the harvesting radii of suppliers in the woodshed and connect these suppliers to their end-users. Our maps illustrate the economically driven nature of the biomass supply chain in Vermont.

While not comprehensive, these maps represent the most complete collection of information about the biomass supply chain in the region to date. As the state of Vermont has identified biomass as an important component of its energy portfolio, this understanding of current biomass energy use will be useful when planning for the future.

II. Introduction

The combustion of woody biomass for heat and power currently makes up a small part of Vermont's energy portfolio, but that portion is growing (Vermont State Energy Plan 2011). Increasing biomass use for both heat and energy production in the state will decrease dependency on fossil fuels or other out of state resources, create jobs in the state, and boost the Vermont economy by allowing dollars to stay local. Biomass contributes to Vermont's economic sustainability and, if managed correctly, has the potential to contribute to environmental and social sustainability as well. Biomass utilization shares many common threads with other sustainability issues in the region. Sustainable harvesting of forest products—of which biomass is one—is essential to the sustainability of Vermont's culture, economy, and relationship with the other regions that share this resource—Quebec, New York, New Hampshire and beyond.

The study of woody biomass in Vermont is not limited to the forests. Related issues include water quality in Lake Champlain, invasive species, human development, and agriculture. These all relate to land management and the movement of resources, and are highly dependent on one another. The use of fertilizers on agricultural fields, or runoff from paved surfaces, can lead to pollution in the lake. The movement of everything from cordwood to boats can impact the spread of invasive species. Although sustainability in the Vermont-New York-Quebec region can be broken into various aspects and focus areas, it is important to understand the connectedness of the system. The proper management of each aspect will contribute to an ecologically, economically and socially more sustainable Vermont.

Biomass is an important piece of this picture. In order to preserve the value of forestland as wildlife habitat, centers of recreation, and carbon sinks, biomass harvesting must consider all aspects of the socio-ecological system. The process of forest regeneration takes decades, so biomass utilization requires both thoughtful, long-term planning and monitoring as well as constant short-term monitoring of cutting procedures, locations, and techniques. Management practices and harvesting guidelines could help reduce the impact of biomass harvesting and utilization but will be more effective if they are coordinated across boundaries. A change in policy in one state could have an effect of the market for biomass in another. In one hypothetical scenario that we considered, Vermont suddenly tightens harvesting regulations and Quebec does not, resulting in a larger portion of Quebec's forests being harvested for consumption south of the border. In this scenario, Vermonters are protecting their forests at the expense of another location. Understanding the policies as well as the current flow of wood across borders will be crucial in seeking to understand the system and plan for the future.

III. Objectives

This project was framed within five objectives. They reflect the questions of our community partners, the Vermont Department of Forest, Parks and Recreation and the Vermont Natural Resources Council's Forests and Wildlife Program.

1. Develop and implement a framework to analyze the region's woodshed by mapping where biomass is being harvested, moved, and used.

2. Describe the current state of scientific understanding about the relationships among forest harvesting practices, carbon sequestration, and forest health.

3. Compare state and provincial policies intended to promote or regulate biomass production and use, identifying best practices as well as any gaps and differences.

4. Based on this comparison, evaluate the potential for regional coordination to improve management of the woodshed. If the analysis indicates better regional coordination is needed, make recommendations for improving woodshed policies.

5. Identify additional information that would help stakeholders coordinate regional management and address cultural concerns of biomass use of the woodshed.

IV. Science:
Biomass Harvesting, Forest Health, and the Carbon Cycle

Our work was grounded in the understanding that action needs to be taken to (a) decrease our dependence on finite and greenhouse gas emitting fuel sources, and (b) increase our proportional use of domestic energy sources. Amid concerns over energy independence and anthropogenic climate change, biomass fuel has been put forward as an alternative way to meet our ever-expanding energy needs. This fuel source fulfills both the need for a renewable energy source that can be managed sustainably and one that can be sourced—for a large majority of the country's states—within the state or from bordering states. Currently 4% of electricity in the US is generated from biomass fuel. Of this amount, 45% was from woody biomass (US Energy Information Administration). In the Northeast, the percent of energy and heat coming from biomass is even higher, and the potential for energy independence is directly proportional to this increase.

In the heavily forested northeastern region of the US, woody biomass is a particularly attractive energy source. Under the right management regimes and with proper harvesting practices its net carbon emissions are less than fossil fuels and may even approach neutrality in the long term. Additionally, it stimulates local economies, reduces reliance on foreign energy, and has the potential to power the area from which it is extracted.

However, biomass energy is not without negative impacts. At the most practical level, it is limited by spatial extent, availability and growth rates. As a product of logging, biomass production can negatively affect certain wildlife and plants and introduce invasive species as well as impede recreational opportunities such as hiking and skiing. Finally, though often touted as carbon neutral, biomass energy's place within the carbon cycle is extremely complicated. Net emissions are largely based on harvesting practices and subsequent management so the use of biomass energy must be well planned and organized if it is to approach carbon neutrality.

Carbon neutrality can be described as a state in which as much or more carbon is being sequestered or offset than is being emitted into the atmosphere (Lal and Lorenz 2012). Biomass, which in the context of this paper will include living and recently dead flora with a focus on woody species being chipped and burned for fuel, gained its carbon neutral reputation through the process of carbon sequestration and the forest cycle. Through this cycle, biomass removes carbon dioxide from the atmosphere via photosynthesis and stores it (Sundquist et al. 2008). When the biomass dies, or is burned, the carbon is transformed again into carbon dioxide and released into the atmosphere. Currently, about 30% of the carbon being emitted by fossil fuels in the United States is offset by terrestrial carbon sequestration (Sundquist et al. 2008). Therefore, when we extract biomass and burn it for fuel, the carbon dioxide being emitted is carbon dioxide that previously existed in the atmosphere, and therefore no 'new' greenhouse gases are entering the atmosphere. If we replace the trees that we cut down and burn, then the carbon emitted during the burning process will be re-sequestered by the newly planted trees, and the carbon cycle continues and no net change in carbon dioxide in the atmosphere occurs.

However, this proposition assumes that trees that are burned will be replaced and that this new generation of trees will ultimately sequester the same amount of carbon as their predecessors. Yet this outcome is far from assured. The net carbon emissions of biomass use depend on a number of factors and the timeframe over which one views the process. Tree species, forest type and harvesting practices all determine the size of the carbon footprint created by extracting and utilizing biomass. Further, different tree species have different decomposition rates and root depth, both of which affect the soil carbon cycle (Yadav and Malanson 2007; Kogel-Knabner 200). Soils are often not recognized by the public as a key issue in determining the carbon neutrality of biomass utilization, but disruptions to the soil can have significant impacts. Some soils are composed of up to 50% carbon. Although this is not common—and the average falls around 11%—it is still important to consider that carbon is emitted from soil when the protective layer of trees is removed and the soil is exposed to the sun and if soil erosion occurs, both which serve as catalysts for carbon emissions from soil (Lal 2005). The removal of surface litter (e.g. leaves and downed woody debris) also leads to decreases in biomass decomposition and carbon input to the soil, and also changes the rate of decomposition by altering the ecosystem interactions (Lal 2005; Johnson and Curtis 2001; Jackson et al. 2000). It is therefore extremely difficult to regenerate a forest that would sequester the exact amount of carbon as the one that has been removed.

The *practice* of harvesting also requires energy inputs. Fossil fuel for equipment is used to access the sites, remove the biomass, process, and ship it, and this must be accounted for in any assessment of carbon fluxes. Therefore, in the search for ways to make utilizing biomass carbon neutral, harvesting practices and land use post-harvest can either shrink the biomass carbon footprint or exacerbate it.

> "*We try very hard to properly manage our forest land.*"
>
> - Vermont Biomass Supplier

In addition to carbon considerations, sustainable harvesting practices become the key to sustaining this resource. Biomass utilization can dramatically alter the structure and function of woodland ecosystems. Conventional forest products such as sawtimber, firewood and veneer logs are largely cut from the main part of a tree's trunk, called the bole. The treetop, leaves and branches are left at the logging site, assuring that nutrients are left to maintain the soil fertility of the forest. However, increased mechanization in wood harvesting as well as an increasing demand for mulch, fiber and biomass energy created from logging residue has enabled the practice of whole-tree harvesting. Under this strategy, the majority of every tree is removed from the forest. Whole-tree harvesting economically incentivizes removing as much wood as possible from the forest. If practiced with efficiency, this leaves little woody material and their associated nutrients in the forest to decompose and transfer woody carbon back into the soil (Littlefield and Keeton 2012). Thus whole-tree harvesting can dramatically affect the continued fertility of the forest.

Biomass harvesting also poses other specific challenges for forest structure (Littlefield and Keeton 2012). Because wood is chipped or otherwise processed in order to prepare it for use, the growth form of harvested trees is not important. Thus gnarled, bent and old trees and even occasionally snags and standing dead trees can be harvested for biomass. However, such trees

tend to have high wildlife value. When harvesting solely for conventional forest products, loggers and landowners can more readily leave such specimens as “wildlife” trees. However, with increasing demand for biomass there is also increasing economic incentive to harvest such trees. Conversely, culling poorly formed trees and chipping them may also benefit the long-term health of tree populations and increase timber value (Briedis et al. 2012). The various potential effects of biomass harvesting on forest structure and health are discusses in more detail below. These impacts are grouped into three major categories: soils, hydrology, and biodiversity.

Soils: As has been described above, biomass harvesting can dramatically affect forest soils. Logging operations tend to expose soils, which may result in a 50% loss of soil organic carbon under certain conditions (Lal 2005). The large equipment used in whole-tree harvesting particularly disturbs the forest floor. Despite the potential for increased carbon emissions, this disturbance may help some seedlings to take root. The new light that bathes the forest floor after the canopy is removed can lead to changes in soil chemistry and the nutrient makeup of the litter and soil which can also lead to the loss of additional carbon. Temperature increase in conjunction with compaction from vehicle activity can also lead to a decrease in beneficial soil bacteria (Lattimore et al. 2009). In addition to the loss of nutrients within the woody biomass itself, harvesting also leads to a net loss of soil nutrients such as nitrogen, potassium, carbon and phosphorus through increased soil leaching (Lattimore et al. 2009).

Hydrology: Harvesting of forest products can also affect the hydrology of forested ecosystems. Most obviously, logging can lead to increased runoff and erosion that in turn can cause a suite of water-quality problems in downstream watersheds. Additionally, soil compaction can create waterlogged depressions in skid trails, landings and logging roads. Finally, removing trees can alter the interception and transpiration rates of forests, which alters infiltration rates to the water table (Lattimore et. al 2009). In response to these issues—and as required by the Clean Water Act—the state of Vermont has developed a list of acceptable management practices (AMPs) for maintaining water quality on logging jobs (VT Dept. of Forests, Parks and Recreation 2010).

Biodiversity: Intense forest products harvesting profoundly affects biodiversity and wildlife habitat. Most obviously it changes and sometimes temporarily eliminates the forest itself. Even when forests remain in production, harvesting can fragment wildlife habitat and create extensive immature forests (Lattimore et al. 2009). This may adversely affect species that require continuous or mature forest including interior nesting birds such as thrushes and tanagers. On the other hand, harvesting may increase habitat availability for other species, such as white-tailed deer and moose, which prefer open areas or early successional vegetation.

As has been described above, harvesting can also lead to a dearth of coarse woody debris. Countless species, fungi, insects, and small mammals rely on this cover for survival (Littlefield and Keeton 2012). Similar to the effects on soils, dramatic changes in the microclimate of the forest floor may also hinder the establishment of native seedlings (Lattimore et al. 2009). This problem may be aggravated by the colonization of previously inaccessible areas by invasive species.

Harvesting may also remove snags, standing dead timber and large downed logs that are also important wildlife habitat, particularly for cavity nesting birds and mammals (Briedis et al. 2012). One study found that 18 mammal species, 23 reptile and amphibian species, 28 bird species, and hundreds of invertebrate species all inhabited snags and downed wood during at least a portion of their lives (Hagan and Grove 1999). Therefore harvesting has the potential to affect a host of forest species.

In conclusion, the forms of harvesting that biomass utilization may facilitate pose specific challenges for forest health and structure. It incentivizes whole-tree harvesting, which can decrease site fertility, remove wildlife habitat and lead to the release of carbon from the soil. Net carbon emissions from biomass production and utilization depend largely on the management of forestland and the way in which logging is conducted. Thus utilizing biomass energy in a sustainable way will involve careful planning.

V. Recommendations for Sustainable Biomass Harvesting

Here we repeat the general recommendations for harvesting timber and biomass and for sequestering carbon made in the 2010 ES 401 report (ES 401 2010). Our amendments based on a broader view of forest health are shown in italics. For more specific management recommendations see Appendix A: Best Management Practices.

Promote mixed-species, mixed-age stands: These stands tend to have higher carbon uptake and storage because of their greater leaf area (Kelty 2006). Furthermore, mixed stands include species that are both shade tolerant and intolerant so that there are trees that grow successfully at all levels; this leads to maximum increase in biomass, which enables more carbon sequestration. Finally, mixed stands enable forests to withstand outbreaks of disease and insect infestation so that even if one type of tree succumbs to disease, other species of trees are able to survive and continue to sequester carbon. Therefore, landowners should follow these recommendations in order to sequester the maximum amount of carbon in forests.

Protect soils: Soils in temperate forests hold about 60% of the total carbon in these forests (Dixon et al. 1994). In order to maximize the soil carbon stock, adequate soil drainage must be maintained and soil disturbances must be minimized. Furthermore, soil carbon stocks can be increased by growing species with high net primary productivity so that more nutrients are released back into the soil, which can store these nutrients for long periods of time. These guidelines are especially important during harvesting, when forest soils are more prone to erosion and contamination. Great care should be taken to avoid exposing mineral soil, which lies deep in the soil profile and is typically a stable carbon store. Only harvesting practices that protect mineral soils should be used.

Protect wetlands in addition to forests: Histosols are a soil type found in most wetland soils and contain approximately 1170 tons/ha of soil organic carbon. Histosols can contain much more carbon than alfisols and spodosols, the principle soil types of the Champlain Valley and the Green Mountains. Therefore, wetlands and hydric soils of any kind must be protected in order to maintain soil quality and its capacity to sequester carbon.

Passive management: Management practices for maximum carbon sequestration should emphasize passive management practices. Unmanaged northern hardwoods still sequester more carbon than forests under any active management, and unmanaged forests may continue to sequester carbon for up to 800 years (Luyssaert et al. 2008). Even if harvested wood becomes furniture, construction materials, or other long-lived wood products, they still might not store atmospheric carbon as well as was previously thought (Harmon et al. 1996). There is a 26% increase in carbon emitted from an actively managed forest, even if wood from the forest is put into furniture (Nunery and Keeton, in press). Some untested active management practices that mimic natural disturbances could promote new growth in the forest, but until these practices are tested further, we recommend passive management to maximize carbon sequestration in forests.

Though this guideline is directly incompatible with logging, biomass harvesting operations may still take the carbon cycle into account. Several studies have suggested that increasing the time between harvesting sessions can actually decrease carbon emissions through

increased sequestration via forest growth (Mitchell et al. 2012, Routa et al. 2012). Thus harvesting of biomass and other products on longer rotations balances carbon sequestration goals with energy and timber revenue. Additional thought should be given to how this might be implemented with private landowners via incentives or subsidies.

Maintain high levels of downed trees, dead standing timber, and coarse woody debris: While specific numbers of downed trees left in the forest following harvesting cannot be determined, harvesting and management practices should maximize the amount of downed trees and coarse woody debris left in the forest so that these trees and debris may continue to store carbon.

Leave slash and logging residue behind: Similar to downed trees and dead standing timber, coarse woody debris, slash and logging residue all contain carbon. They break down faster into humus, and therefore contribute more carbon to the soil carbon store. *These materials also help to maintain lower soil temperatures and therefore help retain carbon and nutrients on logged sites.*

Both of these guidelines also have broader implications for forest health. Logging residue and dead woody structures are critical components of habitat for a range of forest species, from fungi to small mammals. Thus it is important that some snags and dead standing trees remain in the forest after harvesting. Additionally, both hold nutrients that are essential in maintaining soil fertility at the site after harvesting. Though specific recommendations for amounts of woody debris in the literature vary, most agree that approximately 1/3 of the logging residue should remain on site to ensure the future productivity of the forest.

Maintain continuous cover to keep soil temperature low and to keep some litter falling each year: Soil temperature is linearly related to microbial activity. Maintaining a lower soil temperature will help to maintain lower rates of soil organic carbon decomposition in the forest, thereby decreasing the amount of carbon released back into the atmosphere. Also, litter must continue to fall each year in order to maintain the amount of carbon that is returning to the soil carbon store from biotic sources. By maintaining this continuous carbon cycling, more carbon can continue to be stored in the soils of northern hardwood forests.

Large cuts (size specifics not determined by our group) also have negative effects on other aspects of forest health. They can fragment wildlife habitat and open routes for invasive species. In order to minimize this, clear cuts should be avoided.

VI. Policy: Regulations and Incentives in the Vermont Regional Woodshed

Biomass is an appealing alternative energy source for the northeastern United States and Canada because of the abundant forested lands in this region. The use of bioenergy allows these localities to produce their own energy, decrease dependence on foreign fuels, decrease their carbon emissions, and support the local economy. The biomass industry in Vermont is expected to grow in the coming decades as the state plans to obtain 90% of its energy from renewables by 2050 (Vermont State Energy Plan 2011). This means that there will be an ever-increasing need for comprehensive policies regulating biomass use and harvesting.

Understanding the science behind biomass is crucial, but it is equally important to see how that science is interpreted by policy makers at federal, regional, state, and site-specific levels. These policies have fluctuated as understanding of biomass and carbon neutrality have evolved. Although our analysis centers on the Vermont Regional Woodshed, the stakeholders in this issue are affected by policies at the federal level and those of neighboring states. These policies also interact with one another, often in unexpected ways. For example, a policy limiting the allowable harvest in one state may lead to increased imports of wood products from another state, ostensibly negating any efforts towards sustainability the policy intended to promote. By reviewing all of the policies that affect biomass in this region, we hope to identify any gaps and contradictory policies and make recommendations for a cohesive regional perspective on biomass harvesting. Ideally, the various policies in this region will not develop in isolation but rather through the collaborative efforts of the relevant stakeholders.

National-Scale Policy

On the federal level, there are several programs designed to aid the expansion of biomass in the United States. The largest and most widely used program is the Biomass Crop Assistance Program (BCAP), which financially supports owners of forest or agricultural land who have an interest in cultivating biomass crops. BCAP was created in the 2008 Farm Bill and is implemented by the Farm Services Agency. The goal of BCAP is to make sure that commercial-scale biomass facilities have sufficient feedstocks and that growers of biomass crops have sufficient buyers for their crops. Since many biomass crops need several years to become established and profitable, BCAP helps mitigate risk for growers by supporting young biomass crops until they reach maturation. If selected to be part of the BCAP program, crop producers are eligible for reimbursements of up to 75% of the cost of establishing a perennial biofuels crop. They will also receive assistance with the collection, harvest, storage, and transportation costs. For the first two years, producers may receive a payment of up to $45 per ton for the delivery cost (Farm Service Agency 2011). The program also administers an "AIP (Approved Insurance Provider) for up to 15 years for woody crops, with reductions in each of the years when harvests occur" (Buchholz and Volk 2012). The Renewable Fuels Standard (RFS) has set a goal of having 21 billion gallons of biofuels in the national fuel supply by 2022, and BCAP will be an integral part of achieving that.

Regional-Scale Policy

One program important to the discussion of biomass in the northeast is the Regional Greenhouse Gas Initiative (RGGI). This is a regional market-based regulatory system designed with cooperative input from the participating states with the goal of reducing greenhouse gas (GHG) emissions. Nine states participate: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. New Jersey was also part of the initiative until 2011, when Governor Chris Christie withdrew it. Pennsylvania, Quebec, New Brunswick, and Ontario act as observers in the initiative.

RGGI implements a cap-and-trade system for carbon dioxide emissions in participating states, dealing with fossil fuel power plants with generating capacities of 25 MW or greater. The auctioning of emission permits began in 2008 with the first three-year compliance period going into effect in January of 2009. Proceeds from the cap-and-trade go towards energy conservation and renewable energy programs.

According to RGGI, sustainably harvested biomass is carbon neutral when it is converted into electricity. This means that power producers can exclude these emissions from the accounting of their GHG emissions. Each state, however, crafts its own definition of what "sustainably harvested" means with regard to biomass.

New York has the most specific definition of sustainably harvested biomass. Eligible biomass must be from a formally certified location and "remain in a forested state for a time period sufficient to re-sequester the carbon dioxide released through the combustion of the biomass," which is about 100 years (Shaw, 2010).

New Hampshire, on the other hand, defines sustainable biomass more loosely, as "sustainably-harvested woody and herbaceous fuel sources that are available on a renewable or recurring basis, excluding old-growth timber, including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, unadulterated wood and wood residues, animal wastes, biogas, eligible liquid biofuels, and other clean organic wastes not mixed with other solid wastes" (Regional Greenhouse Gas Initiative 2007).

State/Provincial-Scale Policy

The harvesting of biomass fuel in the Northeast is also dictated by regulations at the state level. The most up-to-date information on these regulations reveals that the existing legislation focuses on general forestry and timber procurement standards, and that there is a gap in biomass-specific legislation.

Vermont has several established programs that relate to forest management. In 1970 the state passed the Vermont Land Use Law (Act 250), which has as one of its many criteria before a permit is issued for certain types of development an examination of impacts to productive forest soils for commercial forestry. In 1987, Acceptable Management Practices (AMPs) were established for "Maintaining Water Quality on Logging Jobs in Vermont." These AMPs represent voluntary standards of conduct for logging activities that aim to prevent contamination of state waterways. The goal of the program is to ensure that logging operations do not result in the addition of petroleum products, mud, or woody debris to local waterways. The Vermont

Heavy Cut Law was established in 1997 and requires a “notice of intent to cut” to be filed for “heavy cuts”, in essence clear-cuts of more than 40 acres in extent, on private land. Even though not all whole-tree harvests can be classified as clear-cuts, this regulation is relevant for the biomass industry because of the high percentage of viable land that is privately owned. In 2013 a bill (H. 131, § 2750) for harvesting guidelines and procurement standards was passed in Vermont, which aims to create a model procurement standard for harvesting on state lands, a procurement standard for biomass energy facilities going through the state’s utility permitting process, and—as a separate initiative—voluntary harvesting guidelines for maintaining forest health and sustainability.

Vermont has also produced statewide incentives for the use of bioenergy as an alternative fuel source. In 2004 the Biomass Electricity Production Incentive was initiated, which sets up a relationship with Green Mountain Power to purchase renewable energy credits (RECs) from Vermont farmers producing energy from woody biomass and biogas. The Property Tax Exemption, initiated in 1975, allows Vermont taxpayers exemption from municipal, real estate, and personal property taxes on lands used for renewable energy systems, which today includes biomass facilities (Vermont Statutes, Title 32, Chapter 125, § 3845). Furthermore, the Renewable Energy Systems Sales Tax Exemption in Vermont permits a 100% sales tax exemption for those who purchase Combined Heat and Power (CHP) systems less than 0.2 MW in size (EPA 2013).

In New York State the CHP Acceleration Program initiated in February 2013 provides incentives of up to $1.5 million for the installation of Combined Heat and Power facilities that produce between 0.05 and 1.3 MW. The state also participates in a Solar, Wind & Biomass Energy Systems Exemption similar to that of Vermont, which allows municipal and school district tax exemptions to producers of woody biomass, biogas, and other alternative energy sources (EPA 2013).

For the government of Quebec, there is less incentive than in the northeastern US to dramatically increase bioenergy production because so much of their energy is already locally produced and inexpensive, largely due to the presence of Hydro-Quebec. Yet, bioenergy discussions and provincial panels are still quite active, led largely by the Canadian Bioenergy Association (CanBio). The Forest Biomass Allocation Program is the main legislative initiative actively engaged with biomass production, allowing for the harvest of forest biomass on public forests. The program establishes regional boards to allocate five-year forestry contracts to small-scale developers on federal lands (Luxmore 2010).

Neither New York State, Vermont, nor Quebec have established Best Management Practices (BMPs) for biomass harvesting. BMPS’s are voluntary standards for harvesting and procurement which have been implemented in several other northeast and north central states to guide management of forest resources. Table 1 gives examples of the recommendations associated with woody debris across a range of states BMPs.

	Missouri	Wisconsin	Minnesota	Pennsylvania	Maine	Michigan
Residue	Leave 1/3 of all tree tops from roundwood harvest as FWM and 1/3 of the small cut trees	Leave 10% of the FWM of all harvested trees plus all incidental FWM breakage (10-15%)	Leave 1/3 of the FWM on site (intentionally leave 20% plus 10-15% from breakage)	Leave 15-30% of total harvested biomass as CWM		1/3 - 1/6 of harvested tree residue, dependent on amount preexisting woody material
Large Logs			Retain 5-12 down logs/ha ≥30 cm		Retain 7 down logs/ha ≥38 cm and 2 per ha ≥53 cm	
Snags	Leave 7-15 snags/ha ≥25 cm	Leave ≥7 snags/ha ≥30 cm, preferably ≥46 cm		Leave 2-12 snags/ha (any size)	Leave 7 snags/ha ≥38 cm and 2 per ha ≥53 cm	

Table 1. Measurable criteria for logging residue retention, large logs, and snags as described in the BMPs of Missouri, Wisconsin, Minnesota, Pennsylvania, and Michigan and the biodiversity guidelines of Maine. Empty boxes represent no quantitative criteria given. CWM = Course Woody Debris, FWM= Fine Woody Material. Adapted from Briedis et al. 2012.

Site-Specific Regulation

To a great extent biomass "policy" does not have the most significant influence on the regulatory framework surrounding New England's biomass industry. Where government-sanctioned policy is not in place, biomass procurement is regulated on a site-specific basis. Many people we interviewed stated that the client's (or "end-user's") standards are the predominant drivers of harvesting practices. To what extent this takes into account sustainability and forest health is up to the end-users.

> *"90% of our wood is marked by consulting foresters following site specific silvaculture plans."*
>
> - Vermont Biomass Supplier

Future Goals

The Vermont State Energy Plan published in 2011 made biomass recommendations aimed at several scales. At the state level, the energy plan recommends investment as part of the state budget and incentives that prioritize biomass use over fossil fuels. At community and individual scales, the energy plan also encourages the use of biomass as a way to stimulate supply and encourage the development of biomass infrastructure. Finally, the energy plan suggests that efficiency standards be revised in order to maximize the potential benefits of Combined Heat and Power, by allowing for CHP development that could only be used seasonally. There is an emphasis throughout the document on increasing biomass use with policies that encourage sustainable forest management practices and economic feasibility (Vermont State Energy Plan 2011). The Energy Plan also priorities the efficient use of biomass, including thermal applications.

Quebec developed a similar action plan in 2009, entitled “Developing the Value of Forest Biomass.” One key goal presented in the plan is to facilitate the replacement of fossil fuels with biomass in order to reduce oil consumption, dependence on international energy, and pollution. The action plan also works to increase demand for biomass by increasing awareness and making it more accessible through the Forest Biomass Allocation Program on public lands. It also emphasizes that biomass can offset green house gas emissions, be lucrative, create new jobs, and promote consumption of internally produced energy (Developing the value of forest biomass: an action plan 2009).

In New York State, practically no biomass-specific regulations are thus far in effect. Land-use regulations are largely designated by municipalities instead of on a state-wide level. Therefore, potential bioenergy developers need to abide by very localized restrictions. Biomass projects are regulated by stormwater, solid waste, air and wastewater administrative bodies. The New York State Energy Research and Development Authority has released a “Guide for Siting Small-Scale Biomass Projects in New York State,” for biomass-power projects producing <10 MW in order to assist with better navigation of the disjointed regulations involved in the development process (Boustouler and Reynolds, 2012).

The Vermont Regional Woodshed, as the focus of this investigation, spans multiple political boundaries. Therefore, in this section we considered policies from Vermont, the surrounding states, and the province of Quebec. We discovered that the vast majority of policies focused on harvesting practices at the site-specific level, and were not explicitly regulated by state or federal agencies. Other US states with similar forest resources have voluntary BMPs, which act as guidelines for biomass harvesting. Vermont, however, is currently lacking BMPs, which we have highlighted as an area for improvement. One other policy gap we identified is the lack of a regionally consistent definition for “sustainably harvested” biomass, which we believe is important for preserving forest health and long-term sustainability. A possibility for improvement lies in RGGI, which has already established a platform for regional cooperation on issues of resource management and sustainability.

VII. Mapping:
Visual Representations of the Biomass Supply Chain in Vermont

There are more than 40 suppliers of woody biomass and more than 60 users of woodchips in the state of Vermont, but there is little available data about how much wood is harvested for biomass, who is harvesting and chipping it, and who is buying the woodchips. We sought to identify the location and volume of biomass being harvested and burned and track how chips moved from suppliers to end-users. This information is needed in order to make sound decisions regarding Vermont's goal of increased biomass usage and to understand how a change in policy in one locale might influence the region. We have identified that biomass does indeed move across state and national boundaries. Maps like those presented in this report will be crucial to understanding who will be affected by any change in biomass energy policy.

We collected the majority of information on biomass flows through phone interviews with suppliers and end-users but also used email and information from the Fuels for Schools survey (see Appendix B for a complete list of contacts). We obtained the names of suppliers and end-users from the Biomass Energy Resource Center, using their map search tool (http://www.biomasscenter.org/database/map-search-tool.html) and the Harwood Union High School Procurement Report (BERC 2010), respectively. We were able to contact the majority of people on the lists we were working from and obtained information from 22 of 47 known suppliers and 51 of 67 known end-users (Appendix B).

It became evident that information about biomass harvest was simply not available on a per town basis. There is little to no incentive for suppliers to keep track of where wood is coming from at the township level. However, we were able to obtain a harvesting radius from most of the suppliers we spoke with. Most respondents identified this distance as between 50 and 150 miles (minimum 30 miles, maximum 250 miles) (Fig. 1). Most of the suppliers interviewed obtain their woodchips primarily from within Vermont. However, suppliers located near the state's borders often procured wood from New York, New Hampshire and Quebec, depending on where they are located. According to those interviewed, harvesting radii are constrained by transportation costs associated with trucking fuel, as the cost of gas to transport the chips quickly outweighs the profit from selling them when they are transported far distances. Some of the woodchip suppliers harvest from their own lands, but many others harvest from land owned by others or rely on outside harvesters to supply the wood. Many of the suppliers contacted were sawmills that convert mill residue to chips and do not chip whole trees.

> Why do you transport biomass from Canada to the US?
>
> *"I live right on the Canadian border, I'm bilingual and I've been doing it for 30 years."*
>
> \- VT Biomass Supplier

The annual tonnage sold by the suppliers we interviewed varied widely, ranging from less than 1,000 tons to over 200,000 tons (Fig. 2). Eight of the 49 suppliers on the BERC list of biomass suppliers have gone out of business since 2009, when the list was published. Of these eight, only one supplier contacted had retired, and the remaining seven had either closed permanently or were not currently selling biomass due to a lack of economic viability. Many of the suppliers we originally contacted sold only to the International Paper Company mill in

Ticonderoga, NY, which we did not include in this report because they do not burn biomass for heat or energy.

Though we also contacted hospitals, housing complexes, office buildings, and two large-scale power plants, schools made up the majority of end-users we contacted (Appendix B). Many schools originally installed biomass burners because of state financial support, with some school representatives indicating that at the peak of the program, the state of Vermont funded as much as 90% of the cost of biomass facility infrastructure and installment in their schools. Nearly all the schools began utilizing biomass chips to save money on heating costs; few facilities listed supporting the local economy or reducing carbon emissions among their motivations for converting to biomass. The tons burned annually depended on the size of the facility and the portion of total heat coming from woodchips, but the schools averaged ~550 tons/year and the largest consumers—the Ryegate and McNeil power plants—burned 220,000 and 400,000 tons/year, respectively (Fig. 3).

It appears that a relatively small number of suppliers sell woodchips to the majority of end-users in Vermont (Fig. 4). Due to the time constraint of this project, we were unable to map where biomass suppliers that supply end-users in Vermont also supply out-of-state. Figure 4, therefore, only tells part of the story: it would appear that suppliers are selling only to Vermont end-users, when in fact some of them sell as little as 10% of their product to Vermont end-users, as is the case with Cousineau Forest Products in Hennicker, New Hampshire. Ryegate and McNeil power plants, the largest of the end-users, do not have supplier connections because they are supplied by a plethora of individual suppliers. We were able to obtain supply radii for each of these plants, though: all of the Ryegate suppliers are located within 50 miles of the plant, and all of the McNeil suppliers are within 60 miles. Though it appears that biomass is moving a relatively short distance between supplier and end-user, it is important to remember that the biomass may have travelled as far as 150 miles before arriving at the supplier.

There is a lot of wood coming out of the Bristol area, due mostly to two large suppliers: Lathrop Forest Products and A. Johnson Lumber. Lathrop declined to speak to us or provide data about their biomass business, hence the absence of symbology where Lathrop Forest Products should be in each of the maps. It was clear from speaking with facilities they supply that Lathrop is a prominent supplier in the state of Vermont and it was thus unfortunate that data regarding their supply chain was unavailable.

This information is limited because we focused on just Vermont. We included information about suppliers and end-users outside of the state only if they related to what was going on in Vermont. This inherently limits the information presented in the maps below. Though it looks like there is only movement of biomass in the Vermont area, this is not the case. These maps don't fully report what is going on in the surrounding area.

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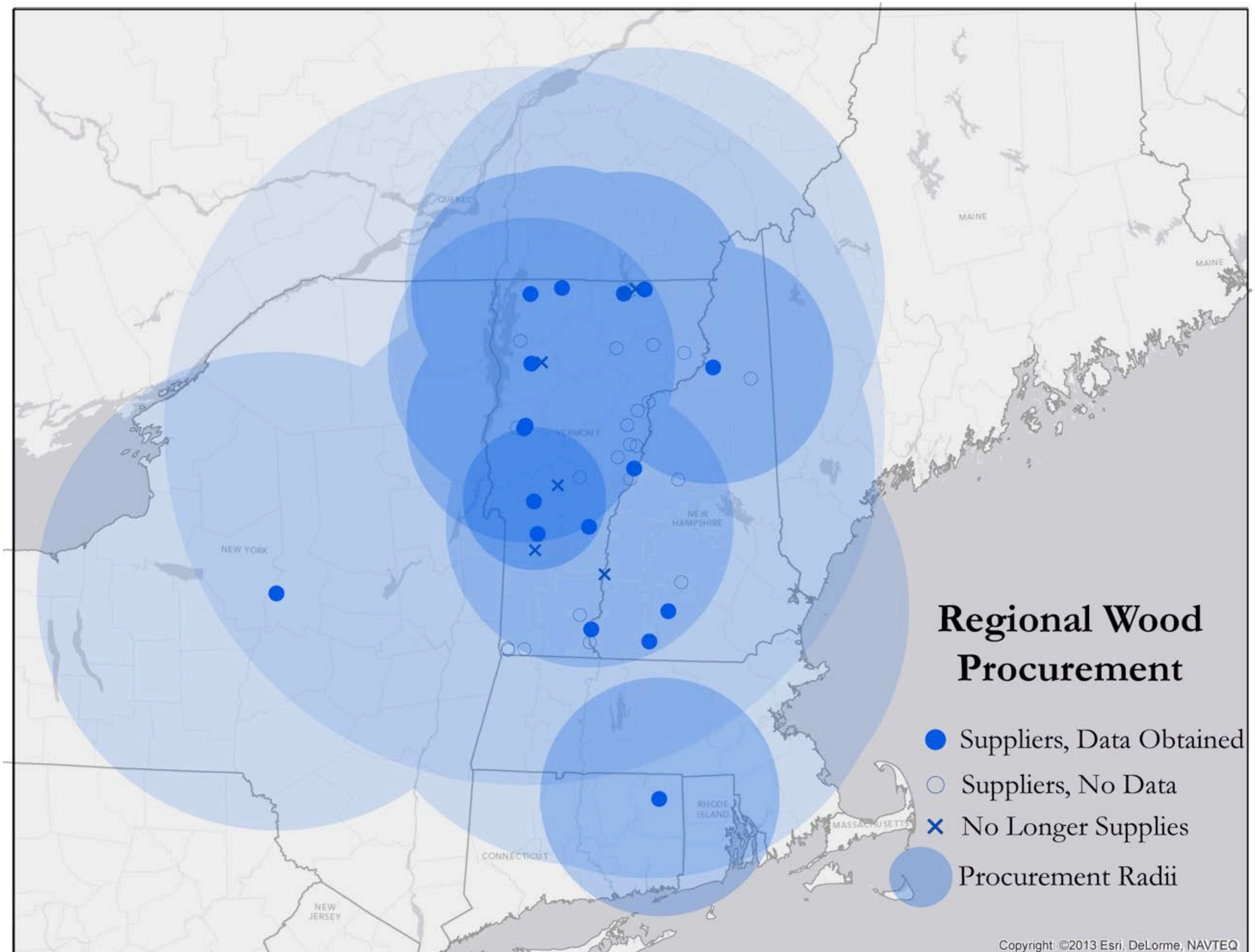

Figure 1. Regional map of the procurement radii (represented by transparent circles) of biomass chip suppliers for end-users in Vermont.

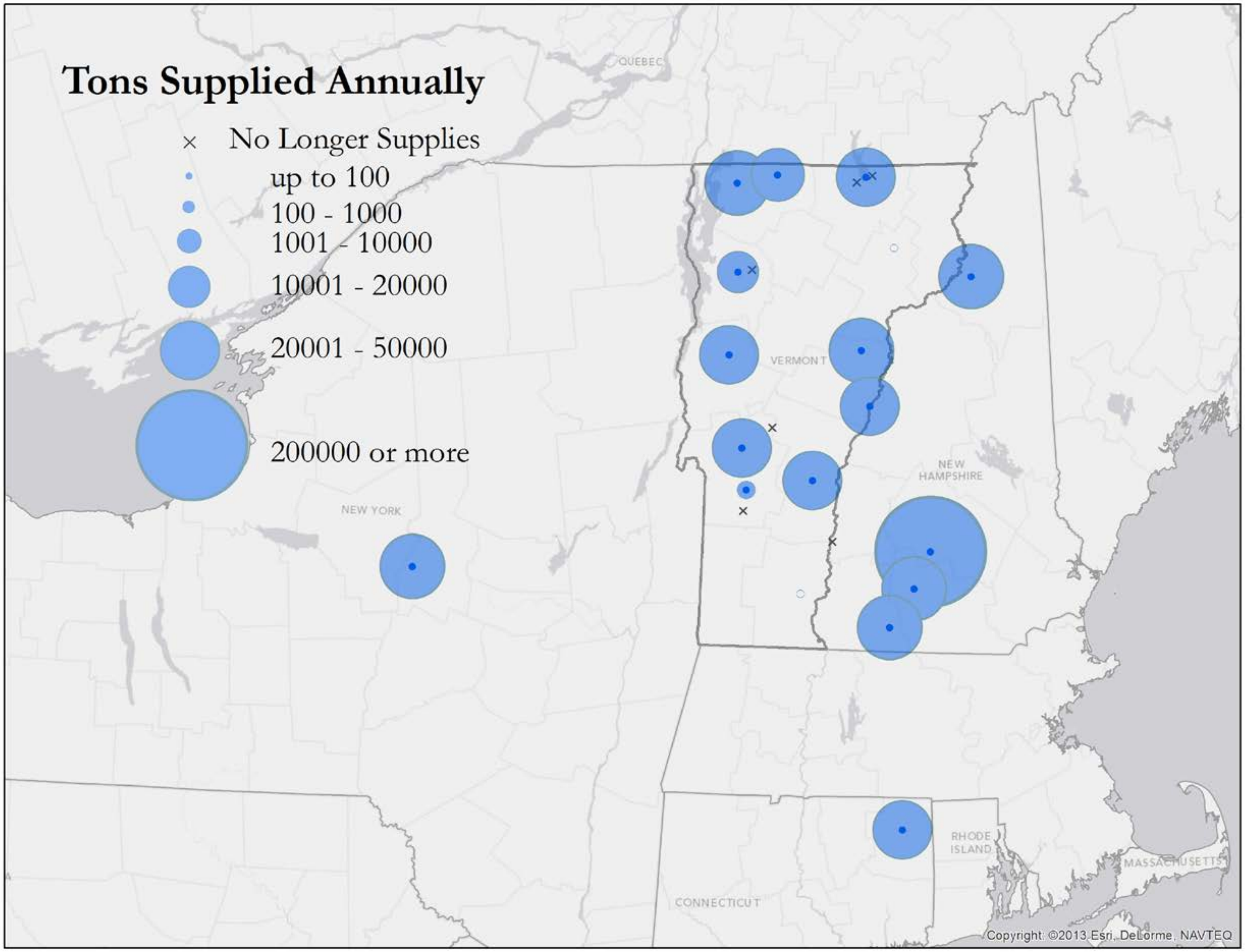

Figure 2. Regional map of tons sold annually by suppliers to facilities in Vermont. Circles depicted with proportional radii representing amount of wood sold and not a geographic area.

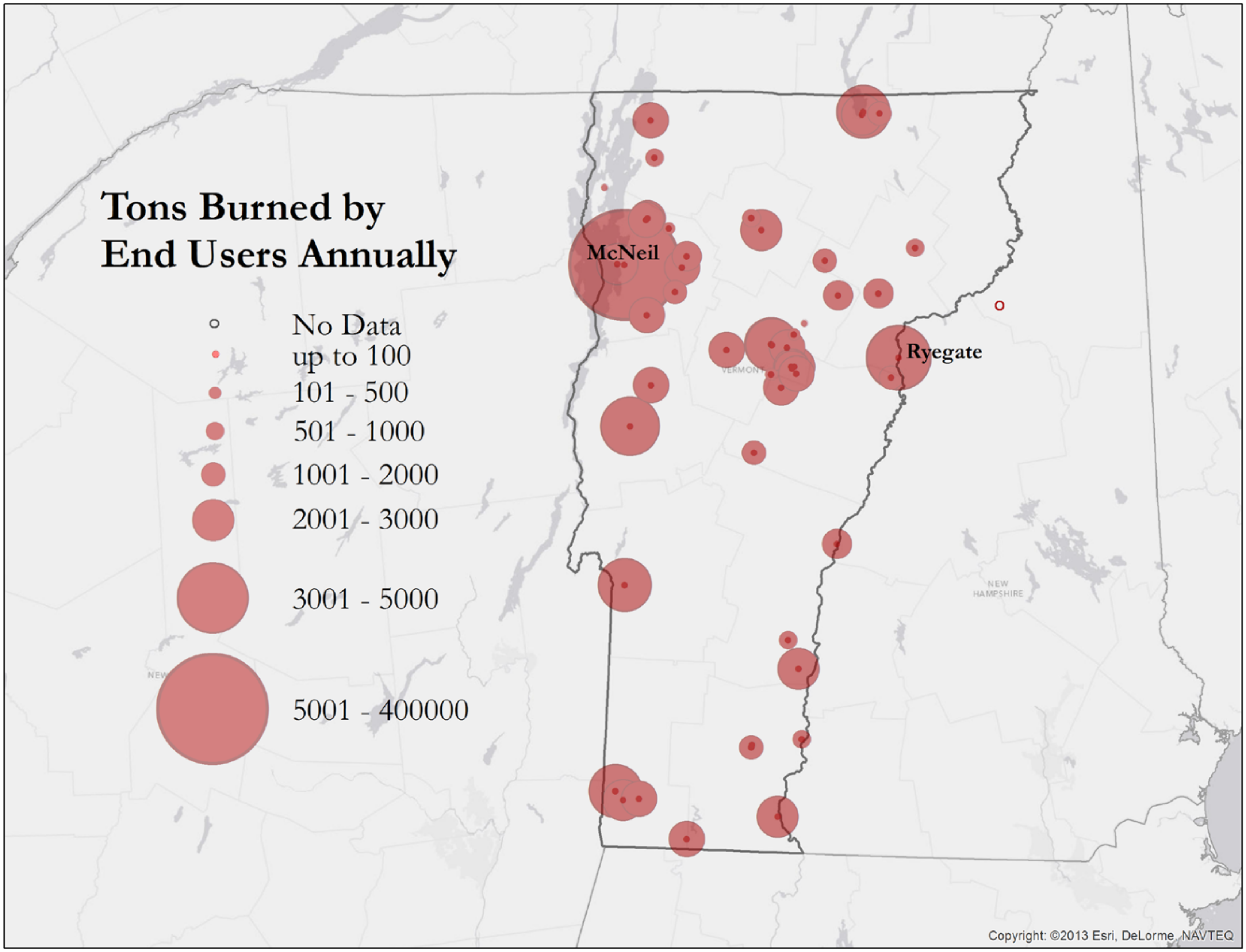

Figure 3. Regional map of tons of biomass burned by facilities in Vermont annually. Tonnage shown as proportional circles.

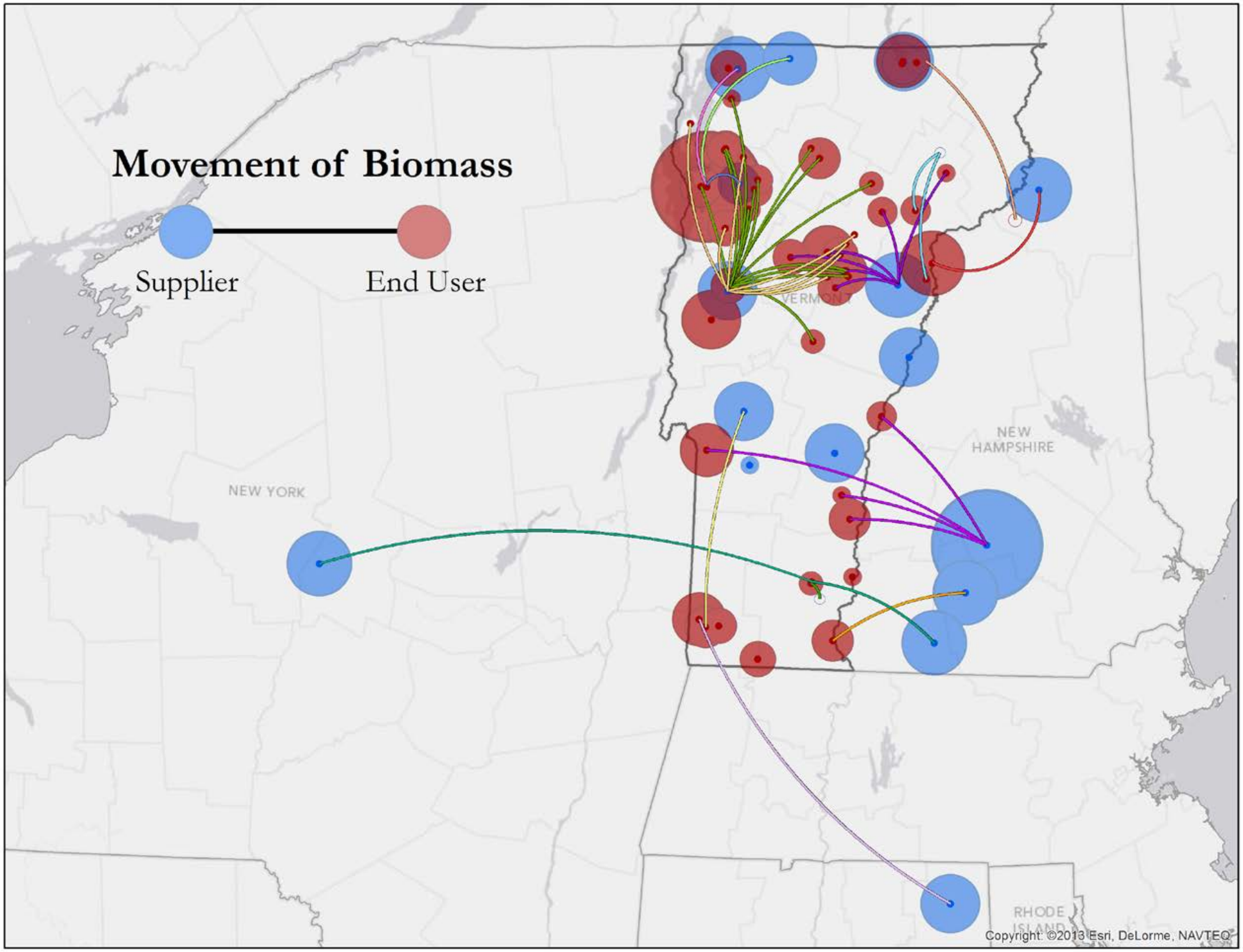

Figure 4. Map of movement biomass in the regional woodshed. Note that some connections have a hollow end point. This is because we were unable to collect data from either the supplier or end-user.

These maps currently represent the most complete set of information about the harvesting, movement and use of biomass collected for this region. This information provides new insights into the current state of biomass movement in the Vermont Regional Woodshed. However, it is far from complete, and more data would enrich the maps and provide a fuller picture of current conditions. We recommend that the following information be collected and mapped:

- Harvesting radii and tonnage sold from each of the biomass suppliers we were unable to contact, as well as those outside the state that supply Vermont end-users that we had no record of.
- More complete information about whom each supplier sells to both in and out of the state of Vermont.
- Information about biomass movement in the surrounding states, as this may impact the Vermont biomass industry even if there are no explicit supplier to end-user connections.

Much of this information may be unavailable or extremely difficult to collect. Still, the more that is known about the biomass supply chain, the better. This information will help when planning for the future by assessing the current situation and allowing planners to envision to effects of additional production, new legislation, or harvesting guidelines.

VIII. Conclusions & Recommendations

Our research put us in contact with people along various links in the biomass supply chain, from owners of small-scale chipping operations to regional-scale power facilities. After familiarizing ourselves with the current policies and accepted scientific knowledge on the production and use of woody biomass, we sought out people in the industry in order to see how these factors might be influencing the flow of biomass within and through the Vermont Regional Woodshed. In all three sections of this report—science, policy and mapping—we identified important pieces that are missing in this state and in the greater region.

Within the scope of our interviews, we found the supply chain to be economically driven, and therefore fluctuating with market controls. We also found that the industry is perceived inconsistently depending on whom you talk to. All of the people we contacted were in the wood-products industry, but several of those we interviewed admitted to having switched the focus of their industry *away* from biomass in previous years because there was not a demand for it. Others had been in the business for multiple decades, and seem to have no problem finding their customer base. We consistently found that vendors of biomass source their product within a radius of ~150 miles. However, this radius was consistently not driven by concerns for sustainability (e.g., reducing one's carbon footprint or use of fossil fuels) but rather by economics, particularly transportation costs or woodchip supply.

While voluntary and less effective than procurement standards, BMPs are an important resource that helps harvesters and landowners manage and log forestland for biomass in a more sustainable way. It would not be difficult for Vermont to create a list of BMPs guiding biomass management and use. Six states and many independent organizations already have such publications. This would guide Vermont as the state seeks to expand its use of biomass energy.

Through our analysis, we recognized that there is very little policy surrounding the transport of biomass. Our discussions with biomass suppliers and users indicate that the transportation of biomass is economically limited, as it is only cost effective to transport biomass chips relatively short distances. However, it is important to be aware of the fact that there are no regulations concerning how biomass crosses international or state borders. Also, because suppliers themselves do not have to comply with environmental regulations themselves, they can shift all responsibility for sustainable use of the resource to the harvesters. Many suppliers with whom we spoke mentioned that they "assumed" their harvesters were complying with various regulations but were not aware of the specifics. Harvesting standards are often only site-specific.

> *(To a chip-broker who supplies Burlington Electric)*
>
> You have to comply with BE's standards then?
>
> *"Oh, I don't know how that works."*

The procurement standards of the state's major biomass plants help ensure the sustainable use of this source of energy. These standards are one of the few effective controls on how forests are managed and harvested currently in place. These should be extended to any new wood energy facilities planned in the state to help ensure the health of Vermont's forests and to limit carbon outputs to the atmosphere.

Another sizeable gap that we identified is the lack of a definition of "sustainably-harvested biomass" in RGGI. The regional agreement classifies biomass as carbon neutral (which as we have demonstrated with our scientific analysis, is problematic in-and-of-itself) so long as it is sustainably harvested, but then allows states to form their own definitions of sustainable harvesting. RGGI provides a platform for regional cooperation between New England states and Canadian provinces (the latter being observers in the agreement), so a definition established through RGGI would affect all of the stakeholders in the Vermont Regional Woodshed. We recommend working through RGGI to establish a regionally consistent definition of "sustainably-harvested biomass" based on the scientific analysis we discussed in this report.

There is also a lack of available data. While we compiled a significant amount of information from interviews, this is incomplete and should be augmented in order to create a complete picture of biomass movement within the Vermont Regional Woodshed. In many cases, the information we sought simply hadn't been collected or was unknown.

Our findings on the fragmentation and inconsistency of biomass policy indicated the need for greater transboundary communication on issues of sustainability. In particular, more international participation like the discussions that were carried out at the Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP) on a regional low-carbon fuels standard (LCFS) would facilitate greater transparency and cooperation on these standards.

In summary, our key recommendations are as follows:

1. Encourage transparency to aid the collection of biomass movement data
2. Develop BMPs in Vermont
3. Promote procurement standards
4. Avoid whole-tree harvesting
5. Decide on a regionally consistent definition of sustainable harvesting

We hope that the information compiled in this document proves useful to the Vermont Department of Forests, Parks and Recreation and the Vermont Natural Resources Council's Forests and Wildlife Program, as well as any other organization or individual interested in biomass energy in the state of Vermont.

IX. Acknowledgements

We’d like to thank our community partners, Jamey Fidel at the Vermont Natural Resources Council and Paul Frederick at the Vermont Department of Forests, Park and Recreation.

We’d like to thank our professors, Catherine Ashcraft and Stephen Trombulak, as well as our class coordinator, Diane Munroe.

We’d like to thank our Environmental Studies Senior Seminar classmates.

Finally, we’d like to thank all those who provided us with information about biomass use at their business, school, or organization.

Appendix A: Best Management Practices

At least 6 states and several outside groups have created guidelines for ensuring the sustainability of biomass harvesting (see Literature Cited). Though Vermont does not currently have a set of best management practices (BMPs) for biomass harvesting within the state, general recommendations can be made based on those of other states and the most recent science on sustainable forestry. Presented here are the guidelines listed in the 2009 ES 401 report concerning biomass harvesting (ES 401 2009). These were amended in the subsequent 2010 report. *The 2010 additions appear in italics.* <u>Our amendments to these guidelines based on the most recent science are underlined.</u>

Sustainable Forestry

1. Forest management goals will be developed with a professional forester while using recognized silvicultural guides.

   a. Due to variability in forest stands due to physical site conditions and past harvests, cutting and silvicultural techniques will vary.

   b. In developing silvicultural techniques for meeting management goals, utilize a combination of the forester's professional judgment and the recognized silvicultural guides, including but not limited to:

      i. A Silvicultural Guide for Northern Hardwood Types in the Northeast by Leak, Solomon and DeBald;

      ii. A Silvicultural Guide to White Pine in the Northeast by Lancaster and Leak;

      iii. A Silvicultural Guide for Spruce-Fir in the Northeast by Frank and Bjorkman;

      iv. A Silvicultural Guide for Developing a Sugarbush by Lancaster, Walters, Laing and Foulds;

      v. Uneven-Aged Management of Northern Hardwoods in New England by Leak and Filip;

      vi. A Landowner's Guide to Wildlife Habitat Management for Vermont Woodlands by Vermont Fish and Game Department;

      vii. Manager's Handbook for Red Pine in North Central States by North Central Forest Experiment Station, U.S.D.A. Forest Service;

      viii. A Guide to Hardwood Timber Stand Improvement by U.S.D.A. Forest Service, Northeastern Area State and Private Forestry; and

ix. Establishing Even-Age Northern Hardwood Regeneration by the Shelterwood Method: A Preliminary Guide by North Central Forest Experiment Station, U.S.D.A. Forest Service.

c. Sustainable harvesting must consider biodiversity as forest management and utilization have impacts on the population of all forest organisms. Different silvicultural techniques have varied effects on biodiversity.

d. *Promote mixed-species, mixed-aged stands.*

Use uneven-aged management by area regulations whenever possible. Uneven-aged, mixed-species stands tend to have higher carbon uptake and storage because of their higher leaf area and are generally less vulnerable to outbreaks of disease and infestation by insects.

2. Average annual removal of woody biomass from the site should not exceed 70% of the average annual growth.

a. Avoid clear-cutting. Canopy openings should be less than 0.25 acres and no larger than 1.25 acres.

The natural pattern for open patches in northern hardwood and spruce-fir forests of northern New England is one of small, disturbed patches within an area of older forest. Harvesting in large, open patches introduces a patch structure significantly different from the natural pattern in these forests. Small-patch silvicultural techniques best mimic the natural pattern.

b. *Whenever possible, maintain continuous canopy cover to maintain low soil temperatures and uninterrupted litterfall.*

Soil temperature is linearly related to microbial activity; thus, maintaining a lower soil temperature will help to maintain lower rates of soil organic carbon decomposition in the forest, thereby decreasing the amount of carbon released back into the atmosphere. Maintaining a continuous litterfall will help ensure that an adequate amount of carbon returns annually to the soil carbon store from the biotic stores.

3. Biological legacies of the forest community should be protected to retain forest productivity and health.

a. No whole-whole-treetree harvesting

Whole-tree chipping damages forest ecosystems by depriving soils of important nutrients derived from residual branches and tops. These features also serve to provide habitat to a variety of wildlife.

b. Retain at least *4 down trees or logs per acre exceeding 15 inches in diameter on average.*

Wood-chip harvests often consist of clear-cutting or whole tree harvesting, including the removal of branches and leaves. These types of harvesting often result in decreased levels of nutrients, including losses of calcium, nitrogen, potassium, magnesium and sulfur.

Utilizing forests alters nutrient cycles as nutrients are stored in roots, stems, branches and foliage of plants and in the forest floor litter. Different harvest intensities and silvicultural techniques should reflect the ecosystem's susceptibility to nutrient depletion. The ability of a forest to recover from a harvesting event is related to the amount of wood left on-site.

Coarse woody debris left at the site after logging is important for forest carbon storage and numerous other ecosystem processes. "Dead wood is an extremely important aspect of the forest structure...coarse woody debris serves as seed germination sites, reservoirs of moisture, and habitat for numerous species of fungi, invertebrates, and vertebrates; it also plays important roles in nutrient conservation and cycling."

c. Tree tops, branches, leaves, needles, and all material less than 4 inches in diameter are left in or near where they were felled

Branches and foliage contain the largest amount of nutrients – including carbon – in trees, and in order to adequately maintain nutrient pools and cycles it is necessary to leave foliage and branches dispersed in the forest.

<u>Approximately 1/3 of logging residue should remain on site to ensure the future productivity of forest soils.</u>

4. *Thinning* cycles should be between 10 and 15 years minimum, *and only occur if it can be done in a way to not disturb soils in such a way as to release carbon that is stored there.*

a. Minimize intermediate treatments to maximize carbon sequestration and storage.

Intermediate treatments should generally raise the average diameter of the residual dominant and co-dominant trees of the forest while improving timber quality.

However, each harvest, with its associated soil degradation and other forest damage, can lead to decreases in total carbon sequestration and storage, and the number of intermediate harvests should be kept at a minimum.

5. Harvesting will promote the protection of residual trees.

a. Residual stand damage should be confined to 10% or fewer of the dominant or co-dominant trees.

b. Great care should be taken to avoid basal wounds on residual trees as basal wounds are ideal entry sites for decaying fungi and bacteria.

6. *Harvest with the longest rotation period possible.*

A forest is able to sequester more carbon if it is able to have longer rotation periods between harvesting. For optimal carbon sequestration and biomass production, we recommend 90-120 years. Due to this length in duration, several plots need to be in rotation.

Wildlife Habitat Protection

1. Maintain snags, dead standing timber, and downed logs.

a. Leave at least 4 standing dead trees 12-18 inches DBH and at least one with >18 inches DBH per acre.

b. Ensure that 5 snags, >10 inches DBH, are left at the site.

2. Take steps to preserve Indiana bat habitat in areas conducive to their habitation.

Every effort should be made to protect Indiana bat habitat. This is an effort to preserve a species that is being threatened by white-nose syndrome, habitat destruction, and cave disturbances. Additionally, as one of two Vermont species listed as endangered, Indiana Bat habitat conservation is mandated by law. While the bats are rare, enough is known to log responsibly. This is an important contribution to a national effort and prevents the obvious issues raised by illegality. The greatest threat posed by our actions is the destruction of summer roosting and foraging habitat. Female bats bear their young in specific types of trees that are easily avoided. Practices should include:

a. Preserve snags whenever possible. Especially those naturally exposed to consistent sun.

b Specific care should be taken in the southern Champlain Valley, the confirmed area of habitation.

c. Retain dead trees with a diameter of more than 12 inches located within 200 feet of streams, lakes, ponds, or wetlands.

d. Retain Shagbark Hickory and Black Locust.

e. Avoid entire areas with known roost trees.

f. Avoid road construction within 100 feet of known hibernacula.

g. Log with a forester with knowledge of Indiana Bat Management Practices.

3. Preserve 100-foot buffers of original vegetation between wetland, stream, pond or lake and active cutting areas. On steep slopes extend this buffer strip to 150 feet.

Riparian buffers offer diverse ecological services and are essential elements of responsibly managed land. They serve to filter suspended sediments from runoff - protecting against water eutrophication - provide habitat for large numbers of animals, stabilize banks, and regulate water temperature. Different conditions assure that buffer width varies at different locations. A broad average suggests that bank stability is preserved with 50 feet of buffer between water and the site; 100 feet assures better water quality due to sediment filtering; and 150 feet preserves habitat

protection. 100 feet seems the most reasonable mark to impose. This width is adequate to remove suspended sediments and nitrogen from the runoff. Beyond this width, numerous small streams on a property could severely limit the productivity of a site. However, an additional site variable is bank steepness, with steep banks necessitating 150-foot buffers.

Water Quality

1. Erosion and sediment control practices are required as outlined in *Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont.*

Soils in temperate forests hold about 60% of the total carbon in these forests. In order to maximize the soil carbon stock, adequate soil drainage must be maintained, and soil disturbances must be minimized. Soil conservation and management is also vital to conserve nutrient cycles. Logging causes nutrient loss through direct removal of nutrients stored in the harvested biomass, increased erosion, and elevated levels of nutrients leached by stream waters for several years following harvesting. Vermont's Acceptable Management Practices on Water Quality are well-developed and adequate for maintaining water quality, with several exceptions:

a. avoid all spring and summer harvesting (and in the fall and winter, only harvest when the soil is adequately dry or frozen);

b. properly buffer and protect streams and special habitats such as cliffs, caves, talus slopes, beaver meadows, vernal pools, spring seeps, and remnant patches of old growth forest;

c. protect and preserve all areas containing histosols, a type of wetland soil that can contain approximately 1170 tons/ha of soil organic carbon, nearly 10 times the storage capacity of other soil orders;

d. avoid rutting that extends beyond the A soil horizon; and

c. re-seed exposed soil with native species to protect against erosion.

Aesthetic and Recreation Considerations

1. Prioritize the safety of any potential individuals who might use the site for recreation.

a. Before and during harvesting practices erect and maintain signs notifying recreational users of the harvesting operation and safety concerns.

b. Consider notifying adjacent landowners as well as the town office of your operation to make the public aware of any potential hazards that may exist.

2. Maintain the natural aesthetic to the maximum possible extent.

a. Maintain a buffer of at least 150 feet between landing areas and any class III or higher roads.

b. Actively minimize the crossing of hiking trails when creating skid trails. Only cross trails at right angles.

c. Maintain a buffer of at least 100 feet to hiking and recreation trails, unless absolutely necessary.

d. Lop treetops 2 feet or less in high use areas. In areas with high deer population, leave slash high enough to protect new seedlings.

Appendix B: List of Interview Contacts

Supplier Company Name	Contact	Street Address	Town	State	Zip	Out of Busi-ness	Tons Sold/ year	Harvest Radius (miles)
A. Johnson Lumber	Dave Johnson	995 South 116 Road	Bristol	VT	05443		7000	150
AB Logging	Dave Atkinson	35 Hodge Road	Lancaster	NH	03584		39700	50
Allard Lumber Company	Clifford Allard	354 Old Ferry Road	Brattleboro	VT	05301			100
Ames True Temper	Joe Phillips	82 Creek Road	Wallingford	VT	05773		250	100
Asa Wilson	Asa Wilson, Jr.	804 Jay Road	Richford	VT	05472			
Barrups Farms/ Green Mountain Mulch	Kevin Barrup	516 Lower Quarry Road	Derby	VT	05829			250 (CT)
Bloom Tree Service		963 Grassy Brook Road	Newfane	VT	05345			
Britton Lumber Company	Doug Britton	7 Ely Road	Fairlee	VT	05045		9305	100
Cersosimo Lumber	Scott Ferland	1103 Vernon St.	Brattleboro	VT	05301			
Chief Logging & Construction	Carl Bogle	1342 Stone Road	South Ryegate	VT	05069			
Columbia Forest Products	Chris Sloan	115 Columbia Way	Newport	VT	05855		8,000-10,000	farthest source is Ohio, ~700 miles
Cousineau Forest Products	John Baker	42 Old Concord Road	Henniker	NH	03242		600000	all over Northeast
Currier - 3D Logging	Phil LaBlanc	459 Main Street	Gorham	NH	03581			

Cyr Lumber	Jean-Paul Cyr	215 Poor Farm Road	Milton	VT	05468			
D.H. Hardwick & Sons	D.H. Hardwick	301 Frances-town Road	Bennington	NH	03442		85300	100
Dave Ducharme	Dave Ducharme	718 Main Street	Greensboro	VT	05841			
Eagle Lumber	Larry Potvin	PO box 880	Stamford	VT	05352			
Fortin Transport	Gerald Fortin	1232 Beebe Road	Derby	VT	05829			100
Gagnon Lumber, Inc	Joe Gagnon	89 Stevens Road	Pittsford	VT	05763		8500	30
George Denagy	George Denagy	PO box 41	Topsham	VT	05076			
Green Mountain Chipping, Inc.	Dave Villeneuve	309 VT Route 15	Jericho	VT	05465	yes		
Green Mountain Forest Products	Bill	957 Highgate Road	Highgate Center	VT	05459		50000	50
Greenwod Mill Inc.	Jane Carrier	2296 Calendar Brook Road	Sutton	VT	05867			
Heath Bunnell	Heath Bunnell	523 Littleton Road	Monroe	NH	03771			
Hull Forest Products	Sam Hull	101 Hampton Road	Pomfret Center	CT	06259		10000	50
Jim Cloud	Jim Cloud	6131 Route 106	Reading	VT	05062		10400	60
Johnson Lumber	Steve Johnson	1613 Chelsea Road	Bradford	VT	05033			
Keith Wolstenholme	Keith Wolstenholme	1408 RT 113	Thetford	VT	05043			
LaBranche Lumber Co	JP LaBranche	1059 VT Route 105	Coventry	VT	05855	yes	33750	50
Lamell Lumber	Ron Lamell	82A Jericho Road	Essex Junction	VT	05452		1300	60

Larry Brown	Larry Brown	PO Box 27	Granby	VT	05840				
Lathrop Forest Products	Jim Lathrop	44 South Street	Bristol	VT	05443			50	
Lawrence White Construction	Nancy Brown	1187 US Rte 7	Danby	VT	05739	yes			
Limlaw Pulp Wood	Bruce Limlaw	Rt 25 Box 10	Topsham	VT	05076		22500		
Longview Forest Contracting- don't supply	Jack Bell	209 Main Street	Charlestown	NH	03603	yes			
Lou Caldwell	Lou Caldwell	1054 Chamberlin Hill Road	Vershire	VT	05079				
Lussier's Sawmill	Anthony Lussier	3723 Water Tower Road	Enosburg	VT	05450		3380	50	
NE Wood Pellet (other VT supplier)		172 Diamond Drive	Schuyler	NY	13340		67000	100	
North Country Procurement	Jamie Damon	450 Main Street	Rumney	NH	03266				
Northeast Wood Products	Rob Kobella	PO box 36	Pownal	VT	05261				
O.E.M. Timber Buyers	Skip Goslin	23 Lower Quarry Road	Newport	VT	05855	yes			
P&R Lumber	Guy Patoine	6231 VT Rt 15	Wilcott	VT	04680	yes			
Plumb Lumber Co.	Alan Plumb	181 Pettengill Road	Andover	VT	05243		2000	50	
S&S Forest Products AKA Vermont Woodchips Inc.	Seth Howe	3007 Wilhall Hollow Road	South Londonderr y	VT	05115	yes			
Sandi Energy, New England Wood Pellet Plant	Joe Howarth		Jaffrey	NH	03452		67000	100	
Scott Fisk	Scott Fisk	Flanders Brook Road	Bradford	VT	05033				
Stanley Tool Inc.	Tom Patterson	3950 Route 100	Pittsfield	VT	05762	yes			
Steve Montgomery	Steve Montgomery	126 North Street	Bethel	VT	05032				
Trees Unlimited	Dave Chesney	613 Hidden Valley Road	Pownal	VT	05261				

End-User Facility Name	Street Address	Town	State	Zip	Supplier	Tonnage Burned Annually
Addison County Courthouse	7 Mahady Court	Middlebury	VT	05753		
All Souls Interfaith Gathering	291 Bostwick Farm Road	Shelburne	VT	05482		
Barre City Elementary School	50 Parkside Terrace	Barre	VT	05641	Lathrop	572
Barre Town Elementary and Middle School	70 Websterville Road	Barre	VT	05641	Lathrop	517
Bennington College	1 College Drive	North Bennington	VT	05201	Hull Forest Products	5000
Berlin Elementary School	372 Paine Turnbike N	Berlin	VT	05602	A. Johnson	140
Blue Mountain Union School District #21	2420 U.S. 302	Wells River	VT	05081	Heath Bunnell	318
Brattleboro Union High School	131 Fairground Road	Brattleboro	VT	05301	D.H. Hardwick & Sons	1290
Browns River Middle School	20 River Road	Jericho	VT	05465	Lathrop	420
Burlington High School	52 Institute Road	Burlington	VT	05408	Lathrop	1200
Cabot School	25 Common Road	Cabot	VT	05647	Limlaw	414
Calais Elementary School	321 Lightening Ridge Road	Plainfield	VT	05667	A. Johnson	90
Camel's Hump Middle School	173 School Street	Richmond	VT	05477	Lathrop	354
Champlain Valley Union High School	369 CVU Road	Hinesburg	VT	05461	A. Johnson	840
Crotched Mtn Rehabiltation Center.	1 Verney Drive	Greenfield	NH	03047		
Danville School	148 Peacham Road	Danville	VT	05828	Heath Bunnell	405

East Montpelier Elementary School	665 Vincent Flats Road	East Montpelier	VT	05651	A. Johnson	115
Emory Hebard Office Building	100 Main Street	Newport	VT	05855		
Grand Isle Elementary School	224 US Route 2	Grand Isle	VT	05458	A. Johnson	68
Green Acres Public Housing Complex	Chatot Street	Barre	VT	05641	Limlaw	575
Green Mountain College	1 Brennan Circle	Poultney	VT	05764	Cousineau	5000
Hartford High School	37 Highland Ave	White River Junction	VT	05001	Cousineau	484
Harwood Union High School	458 VT Route 100	Moretown	VT	05660	Limlaw	910
Hazen Union High School	126 Hazen Union Drive	Hardwick	VT	05843	Lathrop	351
Howard Dean Educational Center	307 South Street	Springfield	VT	05156		
Johnson Elementary School	57 College Hill Road	Johnson	VT	05656	Lathrop	247
Lamoille Union High School	736 VT Route 15 W	Hyde Park	VT	05655	Lathrop	1200
Leland & Gray Union High School	2042 VT Route 30	Townshend	VT	05353	Bloom Tree Service	320
Lyndon Town School	2591 Lily Pond Road	Lyndonville	VT	05851	Limlaw	268
Marty Moore Greenhouse	549 South Street	Bennington	VT	05201		
McNeil	111 Intervale Road	Burlington	VT	05401	within 60 miles	400000
Middlebury College	14 Old Chapel Road	Middlebury	VT	05753	ten suppliers within 75 miles	20000
Milton Elementary School	42 Herrick Ave	Milton	VT	05468	Lathrop	751

Milton Junior/Senior High School	17 Rebecca Lander Dr	Milton	VT	05468	Lathrop	561
Mississiquoi Valley Union High School	100 Thunderbird Dr	Swanton	VT	05488	Pete Foster	534
Montpelier Central Heating Plant	122 State Street	Montpelier	VT	05604	Lathrop	3500
Mt. Abraham Union High School	7 Airport Dr	Bristol	VT	05443	Lathrop	871
Mt. Anthony Middle School	747 E Rd	Bennington	VT	05201	Plumb	850
Mt. Anthony Union High School	301 Park St	Bennington	VT	05201	Gagnon	1210
Mt. Mansfield Union High School	211 Browns Trace Rd	Jericho	VT	05465	Lathrop	984
National Life Group Building	1 National Life Dr	Montpelier	VT	05604	Limlaw	3500
North Country Hospital	189 Prouty Dr	Newport	VT	05855	Ivan Maxwell (QC)	5000
North Country Union High School	209 Veterans Ave	Newport	VT	05855	St. Onge	1049
North Country Union Junior High School	57 Jr High Dr	Derby	VT	05829	St. Onge	357
North Springfield sustainable energy project	36 Precision Dr	North Springfield	VT	05150		400000 (proposed)
NRG Wind Systems	110 Riggs Road	Hinesburg	VT	05461		
People's Academy	202 Copley Ave	Morrisville	VT	05661		
Randolph Union High School	15 Forest St	Randolph	VT	05060	Lathrop	352
Richard Green Trucking		Enosburg Falls	VT	05450		
Ryegate	247 Weesner Drive	Ryegate	VT	05042	within 50 miles	220000
Spaulding High School	155 Ayers Street	Barre	VT	05641	Lathrop	1314
Springfield High School	303 South Street	Springfield	VT	05165	Cousineau	1500

St. Albans Town Education Center	169 South Main Street	St. Albans	VT	05478	Lathrop	245
Twinfield Union School	106 Nasmith Brook Road	Plainfield	VT	05667		
U-32 Jr and Sr High School	930 Gallison Hill Road	Montpelier	VT	05602	A. Johnson	855
Vermont Police Academy	317 Academy Road	Pittsford	VT	05763		
Vermont State House and State Office Complex	115 State Street	Montpelier	VT	05633		
Waterbury State Office Complex		Waterbury	VT	05676		
Weathersfield Elementary School	1862 Vermont Route 106	Perkinsville	VT	05151	Cousineau	250
Weathersfield Middle School		Ascutney	VT	05030		
West River Valley Cares	457 Grafton Road	Townshend	VT	05353	NE Wood Pellet Plant	100
Westford Elementary School	146 Brookside Road	Westford	VT	05494	A. Johnson	180
Westminster Center School	301 School Street	Westminster	VT	05158	S. M. Gallican	253
Whitefield Power Plant	Airport Road	Whitefield	NH	03598	Barrups	
Whitingham Elementary School	4299 VR Route 100	Whitingham	VT	05361	Robert Bros., MA	550
Williamstown Middle and High School	120 Hebert Road	Williamstown	VT	05679	Limlaw	550

Appendix C: Glossary of Terms

Carbon Footprint: the amount of carbon dioxide emitted from the fossil fuel usage of a particular group, person or institution.

Carbon Sequestration: the process of capturing carbon and storing it in a long-term carbon reservoir, such as forests or soil.

Carbon Neutrality: net zero carbon emissions.

Clearcutting: a forestry practice in which the majority of trees in a certain area are cut uniformly at the same time.

Combined Heat and Power (CHP): The simultaneous production of both power and heat from a single fuel source (e.g. biomass).

Biomass Crop Assistance Program (BCAP): a government program aimed at incentivizing the biomass crop market.

Greenhouse Gases (GHG): gases in the atmosphere that absorb and reflect solar radiation. Greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. The burning of fossil fuels has created a significant increase in GHGs in the atmosphere, particularly carbon dioxide.

Riparian Buffer: a forested or vegetated strip along a stream or river, designed to protect the waterway from the effects of adjacent land uses and improve water quality and ecosystem health

Silviculture: the growing and cultivation of trees.

Soil Organic Carbon: carbon held in the soil—the largest terrestrial reserve of carbon.

Woody Biomass: byproducts of forest management, including whole trees, woody plants, limbs, tops, needles and leaves.

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